External Morphometrics of Black Bears, *Ursus americanus* (Carnivora: Ursidae), in the Great Dismal Swamp of Virginia and North Carolina

Eric C. Hellgren
Campus Box 218, Caesar Kleberg Wildlife Research Institute Texas A&M University-Kingsville, Kingsville, Texas 78363

And

Michael R. Vaughan
Virginia Cooperative Fish and Wildlife Research Unit, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061

ABSTRACT— We report body measurements of black bears (*Ursus americanus*) for Great Dismal Swamp, a seasonally-flooded, forested wetland in the Atlantic Coastal Plain. For most body measurements, males reached adult size by 5 years of age and females by 3–4 years of age. Chest girth, and zygomatic circumference were the best ($P < 0.001$) predictors of body mass for both sexes. External morphometrics can be used to predict nutritional condition. Growth models using mass or length data can be developed and growth rates compared among populations. Such comparisons may shed light on black bear taxonomy or habitat quality.

Published data on black bear external morphometrics, other than body mass, are scanty, although common in unpublished theses. Sauer (1975) reported a large data set of external measurements of black bears from New York. Other publications containing data on black bear morphometrics include Poelker and Hartwell (1973:89–104), Cherry and Pelton (1976), and Juniper (1978) from Washington, Tennessee, and Quebec, respectively.

Body morphometrics and growth are important characters in the study of intraspecific regional variation. In a mammal with a wide distribution such as the black bear, such data may provide insights into relationships among environmental factors, particularly nutrition, and genetic potential. For example, mean body masses of adult (≥5-year-old) male black bears range from 96 kg in western Montana (Jonkel and Cowan 1971) to 183 kg in Pennsylvania (Alt 1980), a range mirrored by differences in reproductive rates and attributed to differences in food availability (Bunnell and Tait 1981). Kingsley et al. (1988) found differences in growth curves and body size in three disjunct populations of brown bears (*Ursus arctos*). They attributed variation to differences in system productivity or bear density.

As part of a larger project studying black bear ecology and physiology in Great Dismal Swamp, we collected body measurements from live-captured black bears (*Ursus americanus americanus*) (Hall 1981). Our objectives were to provide baseline data on body measurements by age for black bears in the Atlantic Coastal Plain and to produce prediction equations for body mass based on morphometric measurements.

MATERIALS AND METHODS

We conducted research from April 1984 to August 1986 on a 555-km^2 study area containing the 440-km^2 Great Dismal Swamp National Wildlife Refuge, 57.5-km^2 Dismal Swamp State Park, and adjacent private land. Descriptions of the study area were reported elsewhere (Hellgren and Vaughan 1988, 1989*a*). We captured 101 different bears 120 times with spring-activated cable snares during April through December. Bears were immobilized with a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride at a concentration of 300 mg/mL administered intramuscularly at an initial dosage rate of 6.6 mg/kg. Mass was measured to the nearest kg with a hanging spring scale.

We took measurements on immobilized animals to the nearest mm. Body length was measured from the tip of the snout to the distal end of the last caudal vertebra while the animal was in lateral recumbency. Head length was measured from the tip of the nose to the occiput. Neck girth was measured in the middle of the neck. Chest girth was measured immediately posterior to the scapulae. Circumferences of wrist and elbow (at olecranon process) also were measured. Zygomatic circumference was measured anterior to the ears. The above measurements were taken with a cloth tape pulled snug. Tail length (from base of tail to distal end of caudal vertebra), ear length (from inner notch to tip of pinna), forepaw and hindpaw width (greatest distance across pads), and forepaw and hindpaw length (longest distance along length of pads) were measured with a steel tape. Canine measurements were taken with dial calipers to the nearest 0.1 mm. Upper and lower canine breadths were the distance between the tips of the right and left maxillary and mandibular canines, respectively. Upper and lower canine lengths were measured from the gum line to the tip of the canine. Anterior-posterior lengths and lingual-labial widths of upper and lower canines were measured at the gum line.

We used one-way analysis of variance to examine age differences in physical characteristics within each sex. We did not analyze data for differences by sex because of obvious size dimorphism. Because of small sample sizes and asymptotic growth, all animals ≥ 7 years old were placed into one age category. Samples were pooled across seasons, and all data were analyzed. When data collected after 15 September (n = 19) were deleted, mean body mass for males and females decreased by a maximum of 2.1 and 6.0 kg for any year class. Previous analyses showed an age–season (age catergorized as adults or subadults) interaction (P = 0.06) in body mass for females and non-significant seasonal variation (P = 0.11) for males (Hellgren and Vaughan 1989*b*), probably because of small samples in fall and, subsequently, weak statistical power. We used Tukey's studentized range test to separate means. Recapture data for individuals recaptured within the same year were not included in any analyses. Recaptures in different years (n = seven male, nine female) were treated as independent observations. Simple linear regression was used to develop relationships among body mass and body measurements.

RESULTS AND DISCUSSION

Ages ranged from 1 to 16 years for males (n = 71). All morphometric variables measured varied (P < 0.001) by age except ear length ($\bar{x} \pm$ SE) (119 ± 1 mm, n = 64) and tail length (73 ± 2 mm, n = 65) (Table 1). Based on means separation, we concluded that adult size was reached for most body and canine measurements by 5 years of age. Body mass continued to increase until 6 years of age, with a maximum mass of 198 kg for a 7-year-old individual captured in July.

It is interesting to note the lack of morphometric differences (P > 0.05) between 3- and 4-year-old male bears. The stress of competing for access to reproducing females may reduce body growth in these young males, as nutrients are partitioned away from growth and into demands for mate-searching and male–male aggression (Garshelis and Hellgren 1994).

Females ranged in age from 1 to 9 years (n = 37). Body measurements that did not vary by age (n = 34) were ear length (112 ± 1 mm), tail length (74 ± 3 mm), forepaw width (83 ± 1 mm), forepaw length (85 ± 1 mm), hindpaw length (79 ± 1 mm), and hindpaw length (147 ± 1 mm). Female adult size was reached at an earlier age than male adult size (Table 2). Adult size in body measurements was generally reached by 3 or 4 years, whereas adult canine size was reached by 2 years of age. In New York, female bears attained adult size for all measured characteristics by 2.5 years (Sauer 1975).

Morphometric data are limited for other southeastern wetland bear populations. Adult (>3 years) males and females weighed an

Table 1. Morphometric characteristics (mm unless otherwise noted) of male black bears significantly affected (P < 0.001) by age in Great Dismal Swamp.

	Age (years)																				
	1 (n=3–5)			2 (n=9–14)			3 (n=11–14)			4 (n=8–13)			5 (n=9)			6 (n=3–6)			7+ (n=8–10)		
Characteristics	$\bar{x}$	SE		$\bar{x}$	SE		$\bar{x}$	SE		$\bar{x}$	SE		$\bar{x}$	SE		$\bar{x}$	SE		$\bar{x}$	SE	
Mass (kg)	46.4	7.7	d[1]	63.6	4.8	cd	82.0	6.0	c	83.9	4.3	c	114.6	9.9	b	127.3	5.3	ab	148.1	8.0	a
Total Length	1,227	119	e	1,553	56	d	1,673	30	cd	1,694	38	bcd	1,829	28	abc	1,896	29	ab	1,881	34	a
Head Length	278	18	d	331	8	c	346	7	bc	341	7	bc	370	4	ab	383	7	a	386	7	a
Neck Girth	405	44	c	544	22	b	589	17	b	577	14	b	696	28	a	731	23	a	765	14	a
Chest Girth	626	58	e	821	31	d	900	28	cd	865	19	d	1,021	45	bc	1,074	29	ab	1,157	23	a
Wrist Girth	206	15	c	250	6	bc	276	17	ab	259	6	abc	286	7	ab	286	7	ab	295	6	a
Elbow Girth	290	26	d	363	11	c	369	11	c	389	11	bc	430	14	ab	450	12	ab	469	15	a
Zygomatic Circ.	446	32	d	567	18	c	599	15	c	593	11	c	671	19	b	713	15	ab	750	17	a
Forepaw Width	88	5	e	101	3	d	106	2	bcd	104	2	cd	112	2	abc	119	2	a	116	3	ab
Forepaw Length	86	3	d	96	2	cd	98	2	bc	95	2	cd	106	2	ab	107	3	ab	107	2	a
Hindpaw Width	79	6	d	92	2	c	96	2	bc	97	2	bc	104	2	ab	108	2	a	108	3	a
Hindpaw Length	155	12	c	174	3	b	178	3	ab	179	2	ab	187	3	ab	190	3	a	191	3	a
Canine Length (Upper)	22.9	2.7	d	27.5	0.6	c	29.1	0.4	c	29.5	0.4	abc	30.8	0.8	ab	31.4	0.7	abc	32.4	0.7	a
Canine Length (Lower)	22.5	2.6	b	26.6	0.5	a	27.4	0.3	a	27.8	0.2	a	28.4	0.6	a	29.5	0.5	a	27.3	0.7	a
Canine Width (Upper)	8.9	0.6	c	9.8	0.2	c	10.4	0.1	bc	10.4	0.2	bc	11.2	0.5	ab	11.9	0.5	ab	12.4	0.4	a
Canine Width (Lower)	8.8	0.6	c	10.0	0.2	bc	9.9	0.3	bc	10.5	0.2	abc	11.2	0.3	ab	11.8	0.6	a	11.2	0.3	ab
Canine Breadth (Upper)	49.0	1.6	c	52.3	1.0	c	53.9	0.9	bc	52.9	0.7	c	57.7	1.0	ab	60.0	2.4	a	60.5	1.0	a
Canine Breadth (Lower)	42.0	2.5	d	46.4	0.9	cd	48.5	0.8	bc	48.5	0.5	bc	51.2	0.8	ab	54.4	1.2	a	52.9	0.9	a

[1] Within rows, means followed by the same letter are not different (Tukey's studentized range text, $P > 0.05$).

Table 2. Morphometric characteristics (mm unless otherwise noted) of female black bears significantly affected (P < 0.005) by age in Great Dismal Swamp.

	Age (years)																				
	1 (n=4–7)			2 (n=3)			3 (n=4–6)			4 (n=4)			5 (n=1)			6 (n=3–5)			7+ (n=6–11)		
Characteristics	$\bar{x}$	SE		$\bar{x}$	SE		$\bar{x}$	SE		$\bar{x}$	SE		$\bar{x}$	SE		$\bar{x}$	SE		$\bar{x}$	SE	
Mass (kg)	36.0	4.3	c[2]	35.7	4.4	c	47.4	4.4	c	51.8	1.2	abc	57.5	3.5[3]	abc	60.2	3.7	a	62.5	2.4	ab
Total Length	1.248	27	c	1,297	87	bc	1,433	29	ab	1,500	20	a	1,510		ab	1,487	41	ab	1,462	19	ab
Head Length	271	4	d	285	9	cd	303	3	bc	309	3	ab	305		abc	305	7	abc	322	2	a
Neck Girth	381	15	c	413	22	c	451	16	bc	450	7	ab	480		abc	496	7	b	507	11	a
Chest Girth	614	34	c	640	44	bc	705	15	bc	740	3	abc	740		abc	765	13	ab	801	22	a
Wrist Girth [4]	193	8	b	198	11	ab	209	3	ab	219	6	ab	210		ab	215	12	ab	225	4	a
Elbow Girth [5]	271	9	b	280	10	ab	318	17	a	310	5	ab	320		ab	314	14	ab	329	6	a
Zygomatic Circ.	435	11	d	425	15	bcd	497	11	bc	499	8	ab	515		abcd	521	9	ab	539	8	a
Canine Length (Upper)	21.0	0.8	b	23.9	1.6	ab	25.4	0.7	a	26.0	0.9	a	24.9		ab	26.0	0.4	a	26.1	0.6	a
Canine Length (Lower)	21.3	0.9	b	22.8	0.8	a	23.5	0.4	a	23.6	0.4	a	22.0		a	23.6	0.5	a	23.9	0.4	a
Canine Width [6] (Upper)	7.4	0.1	b	8.2	1.0	ab	8.7	0.3	ab	9.4	0.2	ab	9.3		ab	9.4	0.5	ab	9.4	0.3	a
Canine Width [5] (Lower)	7.5	0.3	b	8.8	0.6	ab	8.8	0.3	ab	8.7	0.1	a	8.7		ab	9.0	0.2	a	9.2	0.3	a
Canine Breadth (Upper)	43.7	0.9	b	47.1	2.4	ab	47.5	0.5	ab	48.8	0.4	a	46.8		ab	50.3	2.1	a	49.8	0.4	a
Canine Breadth [5] (Lower)	40.3	0.8	b	41.5	1.1	ab	42.6	0.7	ab	43.9	0.2	a	42.7		ab	44.1	0.8	a	43.8	0.4	a

[1] $P < 0.001$ for all variables unless otherwise noted. [2] Within rows, means followed by the same letter are not different (Tukey's studentized range test, $P > 0.05$). [3] n=2. [4] $P < 0.002$. [5] $P < 0.001$. [6] $P < 0.005$.

average of 120 and 88 kg, respectively, in Bladen County, North Carolina, (Hamilton 1978) and 102 and 52 kg, respectively, in a bottomland hardwood swamp in eastern Arkansas (Smith 1985). Harvested, adult females from the periphery of Okefenokee Swamp, Georgia, ranged in mass from 46 to 101 kg (Abler 1985). Smith (1985) reported that males reached peak mass by 5 years of age. Although females reached adult stature by age 2 or 3, they continued gaining mass and girth until age 9 or 10. Bears in Great Dismal Swamp became heavier than bottomland Arkansas bears (Smith 1985) by age 6 in males and age 5 in females. Total length and chest girth measurements were also larger for Dismal Swamp males by age 6.

Table 3. Significant ($P < 0.0001$) bivariate regression models with body mass (kg) as the dependent variable for black bears in Great Dismal Swamp, Virginia and North Carolina, 1984–1986.

Sex	Independent Variable (mm)	Intercept	Slope	r^2	Root Mean Square Error	n
Male	Chest circumference	-103.5	0.21	0.95	8.49	59
	Neck circumference	-89.8	0.30	0.94	9.34	59
	Total length	-170.7	0.16	0.72	19.61	51
	Head length	-225.6	0.91	0.78	17.53	59
	Wrist circumference	-102.7	0.73	0.62	22.66	59
	Elbow circumference	-92.5	0.47	0.66	21.59	59
	Zygomatic circumference	-136.4	0.37	0.92	10.57	59
	Forepaw width	-222.9	2.95	0.70	20.31	59
	Forepaw length (no claws)	-201.8	2.95	0.52	25.18	58
	Hindpaw width	-204.7	3.04	0.68	20.80	59
	Hindpaw length (no claws)	-230.2	1.80	0.47	26.89	59
	Canine length (upper)	-153.3	8.40	0.52	25.98	57
	Canine length (lower)	-123.6	7.93	0.25	32.40	58
	Canine breadth (upper)	-293.5	7.03	0.71	20.69	55
	Canine breadth (lower)	-273.4	7.47	0.66	22.12	56
Female						
	Chest circumference	-57.1	0.15	0.92	3.75	29
	Neck circumference	-55.4	0.23	0.89	4.46	31
	Total length	-68.8	0.08	0.53	9.32	28
	Head length	-119.3	0.56	0.72	7.16	31
	Wrist circumference	-69.5	0.56	0.58	8.76	31
	Elbow circumference	-61.6	0.36	0.70	7.46	31
	Zygomatic circumference	-91.4	0.28	0.86	4.97	31
	Canine length (upper)	-34.1	3.42	0.45	9.84	33
	Canine breadth (upper)	-101.0	3.16	0.52	9.27	31
	Canine breadth (lower)	-144.4	4.56	0.46	9.71	32

Regression analyses indicated that chest girth, neck girth, and zygomatic circumference were the best predictors of body mass for both sexes (Table 3). Chest girth has been used commonly to estimate body mass in bears (Cherry and Pelton 1976, Glenn 1980, Nagy et al. 1984), although Swenson et al. (1987) cautioned that interpopulation variation in measurement–mass relationships makes it impossible to produce a single, species-specific equation. These authors also concluded that gender variation warranted development of sex-specific prediction equations.

Morphometric data can be used to predict nutritional condition (Cattet 1990) and make intraspecific comparisons of body size. Differences in body size and growth rates of black bears of different populations resulting from variability in ecosystem productivity may lead to differences in skull morphometry, a key tool in taxonomic analysis. If morphometric variation between populations is best explained by phenotypic responses to the environment, can morphometrics be used to classify animals into subspecies (Pelton 1990)? Such a question is germane to taxonomy of black bears and other species.

Our paper reports on a single, southeastern Coastal Plain population of black bears. We encourage other black bear researchers to standardize the collection and reporting of data on external morphometrics to maximize their utility.

ACKNOWLEDGMENTS—We thank the United States Fish and Wildlife Service, Virginia Department of Game and Inland Fisheries, North Carolina Wildlife Resource Commission, North Carolina State Parks Department, and the Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University. Particularly helpful were D. J. Schwab, R. D. McClanahan, and the entire staff of Great Dismal Swamp National Wildlife Refuge. Technical field assistance was provided by W. M. Lane, J. R. Polisar, and K. M. Meddleton. This project was funded by the United States Fish and Wildlife Service.

LITERATURE CITED

Abler, W. A. 1985. Bear population dynamics on a study area in southeastern Georgia. Georgia Department of Natural Resources, Atlanta.

Alt, G. L. 1980. Rate of growth and size of Pennsylvania black bears. Pennsylvania Game News 51(12):7–17.

Bunnell, F. L., and D. E. N. Tait. 1981. Population dynamics of bears—implications. Pages 75-98 *in* Dynamics of large mammal populations. (T. D. Smith and C. Fowler, editors). John Wiley and Sons, Incorporated, New York, New York.

Cattet, M. 1990. Predicting nutritional condition in black bears and polar bears on the basis of morphological and physiological measurements. Canadian Journal of Zoology 68:32–39.

Cherry, J. S., and M. R. Pelton. 1976. Relationships between body measurements and weight of the black bear. Journal of the Tennessee Academy of Sciences 51:32–34.

Garshelis, D. S., and E. C. Hellgren. 1994. Variation in reproductive biology of male black bears. Journal of Mammalogy 75:175–188.

Glenn, L. P. 1980. Morphometric characteristics of brown bears on the central Alaska Peninsula. International Conference on Bear Research and Management 4:313–319.

Hall, E. R. 1981. The mammals of North America. Second edition. John Wiley and Sons, Incorporated, New York, New York.

Hamilton, R. J. 1978. Ecology of the black bear in southeastern North Carolina. M. S. Thesis, University of Georgia, Athens.

Hellgren, E. C., and M. R. Vaughan. 1988. Seasonal food habits of black bears in Great Dismal Swamp, Virginia-North Carolina. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 42:295–305.

Hellgren, E. C., and M. R. Vaughan. 1989*a*. Demographic analysis of a black bear population in the Great Dismal Swamp. The Journal of Wildlife Management 53:969–977.

Hellgren, E. C., and M. R. Vaughan. 1989*b*. Seasonal patterns in physiology and nutrition of black bears in Great Dismal Swamp, Virginia-North Carolina. Canadian Journal of Zoology 67:1837–1850.

Jonkel, C. J., and I. T. Cowan. 1971. The black bear in the spruce-fir forest. Wildlife Monographs 27:1–57.

Juniper, I. 1978. Morphology, diet, and parasitism in Quebec black bears. Canadian Field-Naturalist 92:186–189.

Kingsley, M. C. S., J. A. Nagy, and H. V. Reynolds. 1988. Growth in length and weight of northern brown bears: Differences between sexes and populations. Canadian Journal of Zoology 66:981–986.

Nagy, J. A., M. C. Kingsley, R. H. Russell, A. M. Pearson, and B. C. Goski. 1984. Relationship of weight to chest girth in the grizzly bear. The Journal of Wildlife Management 48:1439–1440.

Pelton, M. R. 1990. Black bears in the Southeast: To list or not to list? Eastern Workshop on Black Bear Research and Management 10:155–161.

Poelker, R. J., and H. D. Hartwell. 1973. Black bear of Washington. Washington State Game Department Biological Bulletin Number 14. Olympia, Washington.

Sauer, P. R. 1975. Relationship of growth characteristics to sex and age for black bears from the Adirondack region of New York. New York Fish and Game Journal 22:81–113.

Smith, T. R. 1985. Ecology of black bears in a bottomland hardwood forest in Arkansas. Ph.D. Thesis, University of Tennessee, Knoxville.

Swenson, J. E., W. F. Kasworm, S. T. Stewart, C. A. Simmon, and K. Aune. 1987. Interpopulation applicability of equations to predict live weight in black bears. International Conference on Bear Research and Management 7:359–362.

Received 28 June 1994
Accepted 14 September 1994